ANNEX 1

1. FS/FSS SHARING IN THE 37.5 - 40.5 GHz BAND

A. FS Link Budget

The characteristics of a representative DS-3 capacity FS system were selected for the link analysis. These characteristics represent the most interference-susceptible FS system currently in use. Pertinent characteristics of the representative FS DS-3 system are presented in Table 1.

The DS-3 system that was evaluated requires a minimum received signal level of -110.5 dBW to deliver a minimum required threshold BER of 1×10^{-6}. Based on this requirement and Equations 1 and 2, a link distance (d) in an assumed rain attenuation environment absent of radio interference was determined.

$$C = P_T + G_R + G_T - L_P - FM \qquad \text{Equation 1}$$

where: C = Minimum desired signal level for DS-3 system, -110.5 dBW
P_T = FS transmitter power, -15 dBW
G_R , G_T = transmitter and receiver antenna gain, 44 dBi
L_P = free space propagation path loss, dB
FM = required fade margin for 99.999% availability, dB

$$d = 10^{[LP - (20 \log f) + 27.6] / 20} \qquad \text{Equation 2}$$

where: f = FS frequency, 40 GHz

Solving Equations 1 and 2 simultaneously leads to a path length of approximately 2.9 km with a fade margin of 49.7 dB, assuming rain attenuation conditions present in ITU-R rain region K. It should be noted that, if other rain attenuation conditions are assumed, path lengths for the representative FS systems in an environment free of radio interference will be longer or shorter, depending on rain rate, ranging up to about 6 - 7 km.

For the representative DS-3 system, the required C/I to maintain a threshold BER of 1×10^{-6} is 23 dB. This means that the maximum allowable interference level [C + C/(I+N)] from all sources cannot exceed -133.5 dBW (-149.5 dBW/MHz) to maintain the minimum required threshold BER of 1×10^{-6} and a link availability of 99.999%.

Table 1
CHARACTERISTICS OF REPRESENTATIVE CURRENT 37.0 - 40.5 GHz DS-3 FS SYSTEM[1/]

Data Rate/Capacity	DS-3
Frequency Range (GHz)	38.6 - 40.0
Modulation Type	OQPSK
Necessary Bandwidth (MHz)	40
Transmitter Power (dBm)	15
Transmit e.i.r.p. (dBm)	54 (.33m antenna)
Receiver Sensitivity (dBW) (BER 1×10^{-6})	-110.5
Antenna Size (m)	.33 .66
Antenna Gain (dBi)	39 44
Antenna 3 dB Beamwidth (degrees)	1.7 1
Antenna Polarization	H/V

Receiver Noise Figure (dB)	8

[1] The selected FS example is a point-to-point system.

The total assumed FS link budget was defined as a means to accommodate effects of probable self (FS) and external (FSS) interference into a victim FS system while maintaining the required system performance in a rain/atmospheric absorption dominated propagation environment. Based on the starting condition of a minimum [C + C/I] threshold of -149.5 dBW/MHz for BER = 1×10^{-6} and 99.999% availability over a 2.9 km link, a radio interference budget of 2 dB was established by reducing the assumed link distance to 2.3 km to obtain adequate signal margin to overcome an assumed level of radio interference from all sources, while maintaining the desired FS system threshold availability and BER derived from the rain attenuation model set forth above. The resulting 2 dB radio interference margin was then allocated to self (FS) and external (FSS) interference on a 90% / 10% basis respectively. See Recommendation ITU-R F.1094-1. This results in 1.8 dB being allocated to FS self-interference and .2 dB for all FSS interference sources.

Based on the allocated radio interference and attenuation budgets, the [C + C/(I+N)] requirement is now -147.5 dBW/MHz (-149.5 dBW/MHz + 2 dB = -147.5 dBW/MHz) which will allow the interference to degrade the desired signal by 2 dB to -149.5 dBW/MHz and still maintain the specified minimum threshold performance in the rain-dominated propagation environment. The ability to accommodate rain and other atmospheric attenuation and radio interference separately in a link budget is considered critical to overall FS performance and availability objectives, given the propagation environment.

The next step was to determine the interference power levels that would cause .2 dB and 1.8 dB increase in the C + C/(I + N) threshold.

The resulting threshold interfering power levels for self and FSS interference are:

Self: $I \leq$ -152.4 dBW/MHz for 1.8 dB increase

FSS $I \leq$ -162.8 dBW/MHz for .2 dB increase

B. Potential FSS Interference Into FS Receivers

Single Entry Interference. The potential for interference from FSS transmitters to an FS receiver was evaluated by calculating the total FSS interference power density at a victim FS receiver and comparing it to the interference budget. A single entry FSS into FS sidelobe coupling event resulting from the normal assumed operations of the representative NGSO FSS constellation and a representative victim FS system was evaluated.

For the analysis, the representative NGSO FSS satellite was assumed to be at an elevation of 25° above the horizon, and emitting a signal with the maximum power flux density allowed in Article 28 of the Radio Regulations (-105 dBW/m² in a 1 MHz bandwidth). See RR 2578, RR 2582, RR 2583 & RR 2584.

The received interfering signal resulting from this coupling case was assumed to be noiselike, have no polarization mismatch loss, and to add cumulatively to the noise power in the receiver.

The received interference signal level from the FSS scenario was calculated assuming the power flux density limits described in RR 2578, the satellite elevation angles above the horizon, and capture area of the FS antenna utilizing Equation 3. The gain of the FS antenna was determined utilizing the maximum elevation angle, given reasonable deployment assumptions, corresponding to the 2.3 km link presented in this study 2 (8°).

$$I_{FSS} = P_d + G_R - 20 \text{ Log } f + 38.5 \qquad \text{Equation 3}$$

where I_{FSS} = FSS interfering signal power

P_d = FSS power flux density at angles $\geq 25°$ (-105 dBW/m² in a 1 MHz bandwidth)

G_R = FS receiver antenna gain, 12 dBi

f = FS frequency, 40 GHz

Based on Equation 3, the received FSS interference power at the FS receiver is computed to be 146.5 dBW/MHz.

The worst case situation for FS receiver interference susceptibility occurs when the FS signal is fully faded due to rain attenuation. This is the condition reflected in the link budget presented above. For the purposes of this analysis, it was assumed that the FSS signal was also faded. The FSS signal was reduced by 6.8 dB to account for fading due to rain attenuation as assumed in the representative NGSO system proposal. The resulting FSS interfering power level at the FS receiver was computed to be 153.3 dBW/MHz after accounting for bandwidth, and fading factors.

The radio interference budget for a fully faded FS signal allows the FSS interference to be -162.8 dBW/MHz for no impact. The FSS single entry case exceeds this threshold by 9.5 dB, which in turn reduces the available C + C/(I+ N) from -149.5 dBW/MHz to 148.0 dBW/MHz. This will have the effect of increasing the BER of the modeled FS link under heavy rain-faded conditions. Under unfaded conditions on the FSS path, the interfering FSS signal will reduce the available FS fade margin from 49.7 dB to 48.2 dB, and thus reduce the availability of the FS link. It should be noted that the degradation of FS link margins resulting from FSS downlink interference will be mitigated by increases in link margin that result from shorter FS path lengths.

Multiple Entry Interference. Multiple entry FSS space-to-Earth mainbeam-to-sidelobe interference events into a victim FS receiver are readily probable in the case of a single representative interfering NGSO FSS constellation. For the representative NGSO FSS single constellation configuration, multiple entry interference can be modeled by assuming up to three FS sidelobe coupled interfering mainbeam FSS signals entering the FS antenna from an elevation of 22° above the horizon. According to a representative NGSO FSS system proposal, most of CONUS will see two satellites all of the time, and a portion of CONUS will see three satellites up to 75% of the time.

The likelihood of multiple entry FSS into FS interference events also increases substantially when two co-channel NGSO FSS constellations are assumed. This assumption can be based on a satellite diversity FSS to FSS network sharing scheme to effectuate co-channel operations by the subject NGSO FSS constellations. Such a two constellation NGSO FSS model was proposed by the proponent of the representative NGSO FSS system. The resulting multiple entry interference scenario could involve upwards of 130 NGSO FSS satellites. Thus, it can be assumed that up to six FSS mainbeam into FS sidelobe cases could occur simultaneously.

Interference levels for the single representative NGSO FSS constellation multiple entry case could be 3 - 5 dB higher than the single entry case.

The predicted interference power from the two NGSO FSS constellation multiple entry scenario will result from up to six FS sidelobe coupled signals, and, thus, will present at least a 3 dB worse interference condition than the single constellation case.

C. FS Interference Into FSS Earth Station Receivers

Based on the system deployment model indicated for NGSO FSS networks, NGSO FSS earth station receivers are likely to be deployed to address many of the same service applications and, often, in many of the same locations that FS systems are utilized. Since the desired locations of many FS systems are, by definition, flexible and unpredictable prior to actual deployment, and the desired locations of the FSS earth station receivers are often likely not to be known in advance, potential interference from an FS transmitter to an FSS earth station receiver was evaluated by computing a required distance separation for several coupling conditions. The coupling conditions that were evaluated were FS sidelobe-to-FSS mainbeam, FS mainbeam-to-FSS sidelobe, and FS sidelobe-to-FSS sidelobe paths. In addition, two FSS sidelobe antenna gain levels were evaluated. The first ("S/L-1") corresponds to the level presented in a representative NGSO system, and the second ("S/L-2") corresponds to a low sidelobe level implementation of the same antenna.

The pertinent FSS earth station receiver characteristics that were used for this analysis are listed in Table 2. These characteristics were obtained from the representative NGSO FSS system proposal used for the FSS into FS interference study. The selected representative DS-3 FS transmitter characteristics are listed in Table 1.

Table 2 REPRESENTATIVE PROPOSED NGSO FSS SPACE-TO-EARTH CHARACTERISTICS	
Frequency Range (GHz)	37.5 - 40.5
Antenna Gain (dBi)	M/B: 54.4 S/L-1: -1.5 S/L-2: -4.5
Receiver Thermal Noise Level (dBW/Hz)	-201.6
Required I_0/N_0 (dB)	-10.5

The required propagation path loss (L_R) and corresponding distance separation (d) between an FS transmitter and NGSO FSS earth station receiver for the three coupling cases was determined using Equations 4 and 5.

$$L_R = P_T + G_T + G_R - (I_0/N_0) - N_0 \qquad \text{Equation 4}$$

where P_T = FS transmitter power, -92 dBW/Hz
G_T = FS antenna gain in direction of FSS receiver, dBi
G_R = FSS receiver antenna gain in direction of FS transmitter, dBi
I_0/N_0 = FSS Receiver degradation criteria, -10.5 dB
N_0 = FSS Receiver thermal noise level, -201.6 dBW/Hz

$$L_R = 20\,\mathrm{Log}(f) + 20\,\mathrm{Log}(d) + A(d) - 27.6 \qquad \text{Equation 5}$$

where f = FS frequency, 40 GHz

d = Required distance separation (meters)

A = Atmospheric absorption (H_2O, O_2), .00015 dB/m

As a worst case scenario the FS signal was assumed to not be faded for the calculations and the FSS space-to-Earth transmission path was assumed to be fully faded. This is reflected in the FSS space-to-Earth maximum interference power threshold in Table 3. The signals were also assumed to be co-polarized. The results of the application of Equations 4 and 5 are shown in Table 3 for the three coupling cases cited above.

Table 3
RESULTS OF FS TO FSS REQUIRED DISTANCE SEPARATION CALCULATIONS

Antenna Coupling	FS Transmitter Antenna Gain (G_T) (dBi)	FSS Receiver Antenna Gain (G_R) (dBi)	Required Loss (L_R) (dB)	Required Distance Separation (d)
FS M/B to FSS S/L	44	S/L-1: -1.5 S/L-2: -4.5	S/L-1: 162.6 S/L-2: 159.6	S/L-1: 40.4 km S/L-2: 32.5 km
FS S/L to FSS M/B	4[1/]	54.4	178.6	96.6 km
FS S/L to FSS S/L	4[1/]	S/L-1: -1.5 S/L-2: -4.5	S/L-1: 122.6 S/L-2: 119.6	S/L-1: 800 m S/L-2: 570 m

[1/] Measured value at 30° off-axis angle

D. FS Multiple Entry Interference Into FSS Earth Station Receivers

The single-entry FS DS-3 link that was chosen for purposes of this study is an optimistic test case for the analysis of FS interference into FSS earth station receivers. Higher spectral densities produced by

FS DS-1 systems with a transmitter power of 17 dBm in a 5 MHz bandwidth are likely to cause higher levels of interference into FSS receivers at greater distances than the level of interference produced by an FS DS-3 transmitter. Under current FS operational scenarios, there can be a very large number of DS-1 and DS-3 data rate links operating simultaneously at random locations and pointing angles within a given geographic area. Thus, multiple entry FS interference into FSS receivers is quite likely and will couple more interference power, at more antenna pointing angles into the victim FSS receivers. The effect of this will be to extend the period of time that an FSS receiver will experience degradation as it tracks satellites across the sky, making sharing extremely difficult. It is anticipated that higher data rate FS systems using more complex modulation schemes and substantially higher e.i.r.p. (up to 55 dBW e.i.r.p.) than current systems will be deployed at a rapid pace in the near future. These developments will only serve to make FS/FSS sharing even more difficult.

2. SHARING BETWEEN FS AND FSS EARTH-TO-SPACE OPERATIONS

A. Representative FS and FSS System Parameters

The parameters used for the selected representative 47.2 - 50.2 GHz FS and FSS systems are shown below in Tables 4 & 5.

Table 4
CHARACTERISTICS OF REPRESENTATIVE 47.2 - 50.2 GHz DS-1 AND DS-3 FS SYSTEMS[1/]

Data Rate/Capacity	DS-1	DS-3
Frequency Range (GHz)	47.2 - 50.2	47.2 - 50.2
Modulation Type	2 FSK	4 QAM
Necessary Bandwidth (MHz)	5	50
Transmitter Power (dBM)	19	18
Transmit e.i.r.p. (dBW)	35	34

e.i.r.p. density	28.01 dBW/MHz -31.99 dBW/Hz	17.01 dBW/MHz -42.99 dBW/Hz
Receiver Noise Floor (dBW)	-130	-114
Antenna Size (m)	.66	.66
Antenna Gain (dBi)	46	46
Antenna 3 dB Beamwidth (degrees)	0.7	0.7
Antenna Polarization	H/V	H/V
Receiver Noise Figure (dB)	11	13

1/ The selected examples are point-to-point systems.

Table 5
REPRESENTATIVE PROPOSED NGSO FSS EARTH-TO-SPACE CHARACTERISTICS

Frequency Range	47.2 - 50.2 GHz
Main Beam Gain (dBi)	49.3
Sidelobe Gain (dBi)	- 4.5
Data Rate (Mbps)	10.24
Modulation type	QPSK
Necessary bandwidth (MHz)	18
Transmit Power (dBW)	8.5 (rain)
Transmit e.i.r.p. (dBW)	57.8

Antenna polarization	circular
Receiver Thermal Noise Level (dBW/Hz)	-201.6
Required I_0/N_0 (dB)	-10.5

B. FS Interference Into FSS Space Station Receivers

Using the representative DS-1 FS parameters, it can be observed that harmful interference will only be experienced when an NGSO FSS space station passes within, or close to, the FS transmitter main beam. With the assumed representative FS e.i.r.p. level of 35 dBW, and a resulting e.i.r.p spectral density of 28.01 dBW/MHz, when the FS station transmits at an angle of 22° above the horizon, the I_0/N_0 = - 0.17 dB. This is approximately 10.3 dB above the interference threshold of I_0/N_0 = -10.5 dB. This result is based on the computed distance to the victim satellite space station receiver of 2585.5 km with a combined path loss and atmospheric absorption of - 208.27 dB.

It should be noted that the representative DS-1 FS system, which is typical of types now in service. has a receiver input threshold level of -122 dBW, while upcoming 16 QAM and 256 QAM FS systems require -106 and -94 dBW respectively (i.e., an increase in 16 and 28 dB respectively). It can therefore be seen that FS e.i.r.p. levels will of necessity be required to move towards the 55 dBW maximum value in order to provide satisfactory long term performance.

C. FSS Earth Station Interference Into FS Receivers At 49 GHz

The potential for interference from FSS earth station transmitters to FS receivers operating at 49 GHz was evaluated by computing the minimum required distance separation for the most likely coupling condition. The minimum distance separation was determined from the propagation path loss required to reduce the total FSS interference power density at a victim FS receiver to the interference threshold. The interference threshold was based on the receiver noise level and I_0/N_0 = -13 dB. A single entry FSS sidelobe into FS mainbeam coupling case was evaluated for FS DS-1 and DS-3 receivers.

For the analysis, the representative FSS earth station antenna was assumed to be pointed at a satellite at its minimum working elevation angle of 22° and the FS receiver antenna was assumed to be pointed at a FS transmitter in the direction of the FSS earth station.

The received interference power resulting from this case was assumed to be noiselike, have no polarization mismatch loss, and add cumulatively to the noise power in the FS receiver. The FSS transmitter and FS receiver system technical characteristics used in the analysis were summarized in Tables 4 and 5. The required propagation path loss (L_R) and corresponding minimum distance (d) between an FSS earth station transmitter and FS receiver for compatible operation were calculated using Equations 4 and 5 with an appropriate atmospheric absorption factor for 49 GHz, and are summarized in Table 6.

Table 6
RESULTS OF FSS EARTH STATION TRANSMITTER TO FS RECEIVER REQUIRED DISTANCE SEPARATION CALCULATIONS

FS Receiver Type	DS-1	DS-3
FS Interference Threshold (dBW/Hz)	- 206	- 204
FSS Interference Power (dBW/Hz)	- 68.6	- 68.6
Required Loss (dB)	183.4	181.4
Minimum Required Distance Separation (km)	55.5 (radius)	52 (radius)

3. INTERFERENCE MITIGATION TECHNIQUES

Following is a discussion of possible techniques that may be considered as methods to mitigate interference into FSS earth station receivers from FS operations.

Automatic Transmitter Power Control. FS automatic transmitter power control ("ATPC") has been suggested as a means to facilitate sharing with FSS earth station receivers. This method would entail reducing the FS e.i.r.p. by an amount corresponding to some portion of the signal margin designed into the FS link budget to overcome fading due to rain attenuation. ATPC might serve during periods when the fade margin is not required to reduce somewhat the required distance separation between FS transmitters and FSS receivers. However, rain-induced attenuation will often not be correlated with respect to FS interferers and both FS and FSS victim receiving stations, rendering ATPC ineffective, and even counterproductive to the provision of service.

ATPC will substantially increase the cost and complexity of the FS systems and, thus, could jeopardize the commercial viability of FS services. A leading manufacturer of millimeter wave FS equipment has stated that ATPC is not a feature available on currently deployed equipment. If ATPC were to be implemented, it would be accomplished through the use of sensors with a reliable range of operation of 10 - 15 dB. To reliably control power over a wider range would require a completely different approach that would increase the cost of transmitters by an estimated 33 - 50%. It would also require time to implement in new equipment and retrofit into existing installations. This cost and time impact is unacceptable to the operators and manufacturers of FS equipment.

While ATPC may result in reduced distance separations between FS and FSS installations, it appears unlikely that the separation distance reduction afforded by ATPC will have any real measurable benefits for sharing between FS systems and FSS receivers. Even with the use of ATPC the resulting required separation distances will be far in excess of a practical interservice coordination standard, given the defined operational objectives of the representative FS and FSS systems studied. In addition, the use of ATPC causes FS receivers to be more susceptible to FSS downlink interference. In Section 5, it was shown that FSS interference to FS receivers is minimal except when a maximum length FS link is fully faded due to rain. In this case FSS downlink interference into FS receiver antenna sidelobes will impact FS system performance. ATPC will effectively remove the signal margin that protects FS receivers from FSS downlink interference. FS transmitter power control causes the FS receiver to operate in a near fully faded condition all of the time with respect to the FSS downlink signal. The use of ATPC coupled with the high likelihood of multiple entry FSS interference will cause FS performance impacts to occur in less than fully faded conditions, or for links operating at less than maximum path lengths.

Assuming that it would be technologically feasible and economically rational to implement ATPC for purposes of facilitating compatibility with shared FSS operations, the added capability is likely to not protect the operation of both services equally. If it could be implemented, the amount of power control that is possible would depend on a trade-off between the allowable interference to FS receivers from downlink signals, and the minimum acceptable distance separation between FS transmitters and FSS earth stations for compatible operation. From Table 3 it can be seen that the amount of FS transmitter power reduction required to allow uncoordinated FSS earth station receivers for likely coupling conditions may approach or exceed the total margin available for a FS link. This coupled with the increased likelihood of FSS downlink interference associated with ATPC and the cost and time impacts makes power control unworkable.

Diversity. Spatial diversity has been proposed as a means to facilitate sharing between multiple NGSO FSS systems, and has also been suggested for aiding sharing between NGSO FSS systems and FS systems. This interference mitigation method relies on multiple satellites being able to simultaneously communicate with the same service point, such that a change of FSS earth station azimuth angle can be exploited to minimize interference.

The use of FSS spatial diversity may be effective in alleviating interference from traditional fixed service systems with pre-determined static system architectures. It does not appear, however, that this interference mitigation technique will be effective with respect to interference from FS systems, which regularly have links located randomly and pointing in random azimuths and elevation angles. It is quite likely that the ability of FSS systems utilizing spatial diversity to overcome interference from FS systems will be completely offset by the large probability of a FSS receiver that is reoriented to avoid a first FS interferer again being located in the interference area of a second FS transmitter.

Shielding. Various FSS earth station shielding methods have been employed in the past to facilitate coordination between traditional long-haul fixed service systems and FSS space-to-Earth operations. While such shielding has been effective in the past to some extent, it does not appear that the use of shielding would be practical as a means of negating the significant level of harmful interference likely to be experienced from nearby FS transmitters, which may be present in significant numbers. With power level differentials expected of more than 40 dB between the FS transmitters and FSS receivers, shielding of 10-15 dB may be readily achievable. However, any larger amount could require significant time and effort, and the successful outcome would still be in doubt, given the ubiquitous deployment objectives characteristic of the representative NGSO FSS system and the operational characteristics inherent to FS.

4. CONCLUSIONS

For the cases analyzed in this study, the interference caused to an FS receiver by a single entry sidelobe coupling event resulting from the space-to-Earth operations of the representative NGSO FSS system degrades the FS link performance by 9.5 dB, and reduces the available C + C/(I+N) value by 1.5 dB for a fully faded FS link. Under non-faded conditions the FSS interference will reduce the available FS link fade margin by 1.5 dB. The impact of this condition is to potentially render a maximum length FS link unusable under fully faded conditions, to slightly reduce availability under fully faded conditions below the required performance level, or to require slightly shorter link lengths to maintain system performance. These effects will be mitigated by increased FS link margin resulting from shorter path lengths if FS e.i.r.p. is maintained.

The impact from multiple entry FSS space station transmitter interference into FS receivers is predicted to be 3 - 5 dB worse than the single entry case. However if a two constellation, multiple entry FSS interference scenario occurs, interactions from up to six sidelobe coupled FSS signals is possible, and could increase the predicted interference level by up to 6 - 8 dB.

Interference from FS transmitters to FSS earth station receivers was evaluated by determining required distance separations for several coupling conditions. The most likely coupling cases will be FS mainbeam-to-FSS sidelobe, and FS sidelobe-to-FSS mainbeam interactions. It can be seen from Table 3 and from defined FS and FSS operational objectives (i.e., rapid high-density deployment), that distances are far in excess of a practical interservice coordination standard, given the defined operational objectives of the representative FS and FSS systems studied. Advanced FS configurations that will be deployed in the near future are expected to utilize higher order modulation schemes, increased e.i.r.p. and/or dynamic bandwidth and antenna beamwidth capabilities. Thus, future FS systems could be even more susceptible to harmful interference from FSS space-to-Earth operations, or cause an even larger distance separation requirement for FSS earth station receivers than currently deployed FS systems.

Several potential interference mitigation schemes have been proposed as methods to minimize interference from FS transmitters into FSS earth stations. The use of FS automatic transmitter power control ("ATPC"), FSS earth station and/or space station diversity, and FSS earth station shielding are discussed in Section 5. Diversity and shielding may offer small gains in reducing interference, however the high-density, uncoordinated deployment requirements of both services minimize the potential for reducing interference.

The use of FS ATPC was proposed as a method of minimizing interference by reducing the required distance separations between FS transmitters and FSS earth stations. ATPC looks attractive initially, however there are several problems associated with it that render it ineffective. The amount of FS power control required to allow uncoordinated FSS operation approaches or exceeds the total FS signal margin available. In addition, ATPC causes FS receivers to effectively operate in a fully faded condition relative to FSS downlink signals, which in combination with likely multiple entry coupling changes a minimal interference case into a more serious condition. Lastly, no current FS systems are equipped with power control capability, and the cost and time required to redesign, implement, and retrofit FS systems is very high and unacceptable. Furthermore, many cases of uncorrelated fading can occur between interfering FS stations and victim FSS stations, thus rendering the use of ATPC a highly unpredictable method of facilitating interference-free co-frequency operation.

As demonstrated in Section 4 of this study, the separation distances required to protect FS stations from transmitting earth station emissions in the 47.2 - 50.2 GHz band render prospects for viable co-frequency operations by FS and FSS systems impractical, given the assumed deployment objectives in the respective services. Use of an e.i.r.p. mask may prove effective to protect space station receivers from FS emissions, but will only serve to exacerbate the susceptibility of victim FS receivers to interference from earth station transmissions.

Accordingly, it is reasonable to conclude that co-frequency FS and FSS system operations in bands above 30 GHz are not operationally or economically feasible.

APPENDIX C

RADIOCOMMUNICATION STUDY GROUP
ITU-R FACT SHEET

Working Party: ITU-R USWP 9B

Date: 19 November 1996

Document: USWP 9B/3 Rev. 1

Reference: Document 9B/TEMP/7

Document Title: Proposed Amendment to Document 9B/TEMP/7: IDENTIFICATION OF FREQUENCY BANDS ABOVE 30 GHz FOR USE BY THE FIXED SERVICE

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Purpose/Objective:

To contribute to the drafting of Section 7.5 of the CPM-97 Report that addresses WRC-97 Agenda item 1.9.6 concerning the identification of suitable frequency bands for high-density fixed service deployment above 30 GHz.

Abstract:

The introduction clarifies the motivation for WRC-97 Agenda item 1.9.6 which derives from the identified difficulties of band sharing with proposed satellite services, and submits that, in the case of the currently allocated bands in the 30 - 50 GHz range, the obvious workable alternative consists of modifying existing shared co-primary allocations to form exclusive fixed service and fixed satellite service allocations. The three core sections elaborate on the evolutionary shift in the progressing expansion of both the fixed service and the fixed satellite service into higher frequency bands and toward higher deployment densities, and point out that coordination between satellite Earth stations and fixed service stations thus becomes the critical sharing condition which would make either one or both services operationally and economically unjustifiable. The creation of exclusive spectrum allocations within existing co-primary bands is indispensable to allow each service to be deployed to its full potential and to achieve high spectral efficiency. Accordingly, there is a sound technical basis for changes to the Table of Allocations at WRC-97 in conjunction with Agenda item 1.9.6, particularly with respect to the 30 - 50 GHz range. There also appears to be a need for a follow-up WRC-99 agenda item to address Agenda item 1.9.6-related issues in bands above 50 GHz.

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IDENTIFICATION OF FREQUENCY BANDS ABOVE 30 GHz FOR USE BY THE FIXED SERVICE

(Item 1.9.6 of the WRC-97 agenda)

This document is submitted to the January 1997 meeting of Working Party 9B for consideration as an alternative draft of Section 7.5 of the CPM-97 Report.

ANNEX

7.5 Fixed service above 30 GHz (WRC-97 Agenda item 1.9.6)

WRC-97 Agenda item 1.9.6 concerns "the identification of suitable frequency bands above 30 GHz for use by the fixed service for high-density applications". It is motivated by (i) the rapid expansion of large-scale fixed service deployment in ever higher frequency bands; (ii) the unprecedented high and growing deployment densities; (iii) the co-primary frequency allocations to two or more services in the same frequency band, (iv) the growing number of proposals for the introduction of high-density fixed satellite services in the shared frequency bands, and (v) the accumulating indications that such co-primary band sharing between two high-density services tends to critically impair the viability of either one or both services. The most plausible alternatives to co-primary band sharing under such unfavorable conditions are (1) creation of separate exclusive allocations in current co-primary frequency blocks that allow both the fixed service and the fixed satellite service to independently optimize the multiple trade-offs between coverage density, service quality, cost effectiveness and spectral efficiency; and (2) the allocation of new expansion bands for the fixed service, either exclusive or shared with a compatible other service, if suitable spectrum can be identified.

7.5.1. The frontier of fixed service expansion towards higher frequencies is above 30 GHz

ITU-R chose to draw the line between two broad categories of radio-relay systems at about 17 GHz (Recommendations ITU-R F. 1101 and F.1102). Conventional long distance services operate in the bands below this limit, mostly below 10 GHz, where multipath fading is the controlling propagation impairment mechanism and hop lengths of a few tens of kilometers are typical. Above 17 GHz the usable hop lengths are determined by precipitation fading and atmospheric absorption; they are on the order of 10 kilometers and shorter. This frequency range is therefore used for a variety of local access services. The evolutionary shift is gradual over the allocated communications frequency bands between about 11 GHz and 15 GHz that accommodate a variety of fixed services using intermediate hop lengths.

Fixed service deployment progresses towards higher frequencies depending on the available frequency spectrum, service requirements, and technological progress. Recommendation ITU-R F.746 provides summary information on the ITU recommended radio-frequency channel arrangements for radio-relay systems including the frequency bands 17.7 - 19.7 GHz ("18 GHz"), 21.2 - 23.6 GHz ("23 GHz"), 24.25 - 29.5 GHz ("27 GHz"), 31.0 - 31.3 GHz ("31 GHz"), 36.0 - 40.5 GHz ("38 GHz") and 54.25 - 58.2 GHz ("55 GHz"). Local access service deployment is accelerating in all of these bands. Spectrum congestion is already evident in parts of the 18 GHz and 23 GHz bands. The fastest rate of deployment is currently in the 38 GHz band, due in part to the marketplace attractiveness of compact terminals for end user applications. The number of fixed service subscribers in the bands above 17 GHz is currently close to 200 thousand. Based on the accelerating rate of growth it is expected to triple within the next 2-3 years and again over the subsequent 2-3 year period.

7.5.2 The growing variety and high-density deployment of local access systems

Recommendation ITU-R F.1102 covers characteristics of radio-relay systems operating in frequency bands above about 17 GHz. It includes a variety of applications, hop length considerations, and digital radio implementations. The companion Recommendation ITU-R F.1101 supplements it in several important aspects, including a comparison of current and advanced modulation and coding methods. Additional relevant aspects are covered in Recommendations ITU-R F.756 on TDMA point-to-multipoint systems, ITU-R F.1104 on requirements for point-to-multipoint radio systems in the local grade portion of an ISDN connection, and ITU-R F.750 on SDH-based networks. In addition, the March 1996 meeting of Working Party 9B adopted Document 9B/TEMP/15 (Rev.1), a Draft New Recommendation on Radio

Local Area Networks (RLANs) that are listed in Recommendation ITU-R F.1102 as an important new application category in the bands above 17 GHz. The band-specific radio-frequency channel arrangements are provided in Recommendations ITU-R F.595 (18 GHz), F.637 (23 GHz), F.748 (25, 26 and 28 GHz), F.749 (38 GHz), and F.1100 (55 GHz).

This group of ITU-R Recommendations provides a solid framework for local access radio system deployment in the bands above 17 GHz, in general, and in the bands above 30 GHz, in particular. The rapid development of local access radio systems is further documented in more recent publications, e.g. in the ITU TELECOM 95 Technology Summit, Volume 2 of Speakers' Papers (H. P. Petry, Design Aspects of a Flexible Radio System in Access Networks, pp. 325-329, and K. Kohiyama, Advanced Wireless Access Systems, pp. 341-345). The following deployment summary is derived from Recommendation ITU-R F.1102 and from the quoted publications.

Example Current Deployments	Example Future Deployments (near-medium term)
Local access	Radio local area networks (RLANS)
User to user building LAN interconnection	Multimedia capability
End office to user building multiplexed links	Transmission rate and bandwidth on demand
Inter-cell links for cellular and PCS systems	ATM compatibility
Transportable radio for optical fiber backup	Expanded portability of user terminals
SDH access network links	Local distribution of television programs

The densest current deployment is in urban and suburban business areas and in industrial areas. Future dense deployment is expected to extend to residential areas, spearheaded by local distribution of television programs in competition to Cable TV and other new broadband service offerings to the home. The variety of network configurations includes: conventional point-to-point (P-P), conventional point-to-multipoint (P-MP), and combinations thereof, e.g. P-P systems deployed in multisectored P-MP configurations. High-density deployment of independent P-P links similarly results in clusters that assume the essential characteristics of P-MP deployment. The densest deployment cases have reached the range of 1 to 10 fixed terminals per square kilometer; they are expected to increase several fold within a few years.

7.5.3. The evolutionary shift includes inter-service frequency band sharing conditions

All of the fixed service allocations above 17 GHz are presently shared on a co-primary basis with satellite services, mostly with the fixed satellite service. Fixed service deployment started without any sharing restrictions in effect, and there is as yet no satellite deployment in the bands above 17 GHz, except experimental. Fixed satellite service planning for these bands started on the premise that the established sharing conditions in the 4/6 GHz and 11/14 GHz bands can be replicated above 17 GHz. However, the evolutionary shift from below to above 17 GHz introduces in both the terrestrial and satellite fixed services entirely new conditions which greatly reduce mutually tolerable sharing above 17 GHz. At the core of the problem is the increase in either actual or potential deployment densities in the two services. This is due in part to the substantial reduction of the physical size of both fixed satellite service and fixed service antennas allowed by the use of higher frequencies that results in a dramatic expansion of viable end user service applications. This is also due to the increased deployment densities made possible by higher signal attenuation in the higher frequency bands.

The critical sharing aspect is the coordination between satellite Earth stations and fixed service stations. Geographical separation is facilitated in the 4/6 GHz and 11/14 GHz frequency bands by the predominant long distance and regional fixed service deployment, and by the comparatively low density deployment of satellite service Earth stations. In addition, frequency separation is facilitated by the comparable radio channel bandwidths of terrestrial and satellite services in those bands. Nevertheless, the proliferation of 4 GHz Earth stations in some parts of the United States has made it virtually impossible to add new fixed service links in this band through coordination.

In the bands above 17 GHz the fixed satellite service proposals aim at even higher densities of compact new Earth stations, the predominant number of which are intended to be placed directly at customer premises. While this is attractive in offering a complementary service to the existing and future fixed service subscribers, it is highly restrictive in the case of band sharing because it would require either collocation of terminals of the two services or placing them closer than the required separation distance. Since the planned deployment densities of satellite Earth stations are comparable to those of the fixed service, the extent of effective geographical separation is marginal at best. The effective use of frequency separation is also critically reduced by the large channel bandwidths of the proposed satellite services in the bands above 17 GHz, which are in many cases are many times larger than the channel bandwidths of the existing and planned fixed service links. Accordingly, band sharing between fixed service and fixed satellite service systems by coordination becomes largely ineffective for practical purposes in most frequency bands above 17 GHz.

7.5.4 Impact on WRC-97 agenda item 1.9.6

Propagation conditions, available technology and business conditions focus the WRC-97 agenda item 1.9.6 on the 30 - 50 GHz frequency range that includes two major bands allocated to fixed terrestrial and satellite services on a co-primary basis: 37.5 - 40.5 GHz and 47.2 - 50.2 GHz. ITU-R sharing studies that are being carried out for affected bands above 17 GHz provide sufficient indication that high-density fixed terrestrial and satellite services with collocated or closely spaced subscribers are in principle incompatible for band sharing purposes.

The underlying reason is two-fold: (i) the required inter-service separation distances are large in comparison with the intra-service distances; and (ii) inter-service frequency separation is rendered ineffective or impossible due to the comparatively very large radio-frequency channel bandwidths of the proposed fixed satellite services. This means that, if band sharing were imposed, either one or both services would become operationally and economically unjustifiable.

In the specific cases of the 38 GHz and 48 GHz bands the straightforward solution consists of band segmentation which would allow each service to be deployed to its full potential in terms of subscriber density, system capacity, service quality, cost effectiveness and spectral efficiency. This solution is readily available because in each case a 3 GHz bandwidth is allocated on a co-primary basis. The feasibility of this solution is demonstrated by the extensive and rapidly expanding high-density fixed service deployment in the 38 GHz band, which currently utilizes only one half or less of the 3 GHz wide co-primary band allocation. Near-term future fixed service deployments in the 48 GHz band are very likely to follow the same or a similar pattern.

As a result of the studies in response to WRC-97 Agenda item 1.9.6 it is clear that there currently exists a sound technical basis for remedial action at WRC-97 through appropriate changes to the Table of Allocations in the range of 30 - 50 GHz. Extant issues relating to Agenda item 1.9.6 concerning the bands above 50 GHz appear to require a follow-up WRC-99 agenda item.

APPENDIX D

WILLKIE FARR & GALLAGHER **MEMORANDUM**

TO: Pantelis Michalopoulos

FROM: Joseph M. Sandri
Michael F. Finn
C. Grace Campbell

RE: Millimeter Wave Drafting Group -- AD Hoc MW Document 49

DATED: November 13, 1996

Please find enclosed the draft responses to the requests for information agreed to by WinStar at the last meeting of the Millimeter Wave Drafting Group (October 25, 1996).

The materials enclosed respond to the questions asked by the Ad Hoc Millimeter Wave Committee:

1. Re-use Density.
   - See Appendix A, Walt Roehr's paper entitled Fixed Service Point-to-Point Hubs.
2. Length Margin
   - See Appendix B, AD Hoc MW/48.
3. Actual Spec Sheets.
   - See Appendix C.
4. Antenna Patterns and Gains.
   - See Appendix C.
5. Receiver Characteristics
   - See Appendix C. See generally Appendix B, AD Hoc MW/48.

6. Advanced Systems

- See generally Appendix C. Also, note that on Aug. 22, 1996, WinStar Wireless, Inc. issued a request for proposal (RFP) to the major equipment suppliers concerning the creation of an advanced 38 GHz system. The RFP will engender responses from a wide variety of manufacturers. As such, a wide variety of advanced system designs will be available. This of course creates substantial uncertainty as to the exact character of all advanced systems. However, it is reasonable to assume that advanced systems will pursue higher powers, higher modulation schemes, and greater protection from outside interference sources.